MARKED UP VERSION OF THE SUBSTITUTE SPECIFICATION

Projection lens, in particular for microlithography

Background of the Invention

The invention relates to a projection lens, in particular for microlithography and having a lens arrangement, according to the type defined in more detail in the preamble of claim 1. The invention also relates to a method for producing microstructured components with the aid of a projection exposure machine.

It is already known from US 4,871,237 to tune a lens as a function of barometric pressure, specifically via the refractive index of a filling gas in the lens interspace. It is possible, for example, to correct spherical aberration, coma and other faults by a suitable combination of interspaces. However, it is a disadvantage of this lens that other faults are initiated with the removal of one error, for example a spherical aberration.

US 4,676,614 discloses a projection exposure machine which comprises a gas chamber to which pressure can be applied. Image errors caused by a change in atmospheric pressure can be compensated by a specific application of pressure.

US 5,559,584 discloses introducing protective gas into the interspace between a wafer and/or a reticle and the projection lens in the case of a projection exposure machine for producing microstructured components.

In the case of lithographic lenses, spherical aberration, inter alia, arises as image error owing to environmental influences, such as change in air pressure, for example. Other parameters are lens heating and compaction, which likewise lead to spherical aberration. Particularly in the case of a high numerical aperture, the absolute value of the spherical

aberration becomes very large and no longer tolerable given the required accuracies.

In addition to US 4,871,237, mentioned at the beginning, it is known to compensate barometric and weather-induced pressure changes by wavelength changes in the case of DUV lenses. However, for 365 nm, 193 nm lenses this method no longer functions and specifically the chromatic correction of the lenses, that is to say the use of different materials, causes the different variation in the refractive indices with the wavelength to lead to image errors which cannot be tolerated.

It is also known from practice to compensate residual errors, caused by environmental influences, by using z manipulators, that is to say lens elements which can be actively displaced in the direction of the optical axis. However, it is disadvantageous of this method that in addition to the large outlay required therefore other errors are once again introduced thereby as well.

It is therefore common to all known methods that they more or less effectively compensate spherical aberration but at the same time once again introduce other errors, or act only incompletely. A complicating factor is added when the optical materials used, in particular lenses, consist of different materials such as, for example, calcium fluoride and quartz glass, because this gives rise to differently varying refractive indices over the wavelength, should it be desired to manipulate over the wavelength.

Summary of the Invention

It is the object of the present invention to create a projection lens which has with fewer lenses a very good quality, in particular also in the case of a high aperture, it also being desirable to provide correction options at the same time. It is desired, in particular, to permit correction of the constant field component of a spherical aberration. It is

likewise the object of the invention to create a method for producing microstructured components in the case of which spherical aberration can be corrected as far as possible.

Given parallel chambers and elements bounded by flat surfaces, only spherical aberration occurs in effective telecentric systems when there is a change in refractive index, in particular downstream and upstream of an end plate. This fact has now been utilized in the device according to the invention. Pressure changes in such a chamber change the spherical aberration. The same also holds for the change in a gas composition. This state of affairs is now utilized according to the invention for active manipulation for spherical aberration.

If, in this case, the manipulation chamber is disposed between a last end plate upstream of the substrate to be illuminated and the optical lens situated adjacent to the end plate, which in this case must be flat on the side facing the end plate, the spherical aberration produced "artificially" in this way can avoid or appropriately correct or compensate an aberration of the lens by changing the pressure in the manipulation chamber and/or the gas composition and/or the active control thereof.

The same also holds when the manipulation chamber is installed between the template and the image plane.

It is advantageous to set an offset of the refractive index in advance via a specific initial gas mixture, in order to permit changes in refractive index in both directions, that is to say raising and lowering it.

In other words, if the refractive index is changed in the manipulation chamber, spherical aberration (constant field characteristic) is introduced virtually exclusively. The change in the refractive index is achieved according to the invention by the selected composition of the gas or gas mixture to be introduced into the manipulation space, and/or of the pressure.

In order not to introduce any new errors by additional pressure, for example by sagging of the surfaces delimiting the manipulation chamber, the elements closing off the manipulation chamber must correspond to the specified diameter/thickness ratios.

In a very advantageous development of the invention, it can be provided that a further manipulable gas interspace is provided in addition to the manipulation chamber. The further gas interspace can be provided with a low refractive power, that is to say at least one surface delimiting the gas interspace in the z direction is provided with a slight curvature. If a gas or a gas mixture is likewise introduced into this gas interspace, the refractive power can be varied by changing the gas mixture or else by a pressure change. It is possible in this way to change any field curvature arising on the substrate to be exposed. Specifically, imaging as accurately as possible on the flat substrate requires the absence of any field curvature. If, for example, the field curvature changes owing to lens warming, this disadvantageous field curvature can now be removed according to the invention by the further manipulable gas interspace. This holds, in particular, whenever the latter is situated as close as possible to the substrates to be exposed. At the same time, it is thereby avoided that other errors are produced again thereby.

The construction according to the invention of an optical element according to claim 8, which more or less has a shape which is at least approximately plane parallel, and the specified thickness, which is greater by comparison with known optical elements such as, for example, an end plate of a lens yield the advantage that, for example, owing to the plane parallelism of the optical element there is only an insubstantial variation in image errors arising from the thick element over the field. This element always reacts identically over the image field, because the lens is telecentric in this region. Since this optical element has no radii of curvature or

at least none worth mentioning, no radii can exert an unfavorable influence in any way at all, in particular when the field increases or the aperture increases, for example. In other words: the optical element having the dimensions according to the invention no longer leads to any variations, and this means that specific aberrations in the widely opened lens can be better predicted in principle and can in this way be corrected further at the front or as early as in the input region.

When, in a very advantageous embodiment of the invention, it is provided that the optical element and a further optical element of the sixth optical group enclose a gas chamber, in which case it holds for the radius of curvature R3 of the surface of the second optical element, which faces the first lens, that: R3 > 3000 mm, preferably > 5000 mm, this produces a quasi plane-parallel gas chamber which can be used as manipulation chamber in a very advantageous way for the invention.

A further, very advantageous and not obvious development of the invention in the use of an optical element in the sixth lens group with the specified radii of curvature and diameter/thickness ratios consists in that a lens with an aspheric is provided in the first lens cluster.

Corrections, such as the removal of shell errors and field curvature, for example, can be achieved with the aid of the aspheric according to the invention as early as in the input region of the lens. This holds, in particular, in the case of very widely opened lenses, in particular when the aspheric is fitted as near as possible to the input of the lens, at least in front of the first bulge, at best already on the first curved surface.

It is thereby possible according to the invention to achieve apertures of at least 0.75, preferably 0.85, it being possible, nevertheless, still to fit a very thick optical element on the

output side, for example a thick end plate. Since an optical element in accordance with claim 1 no longer experiences variations, it is possible, for example, to predict the aberration, that is to say how it develops in the lens. The aspheric according to the invention can be used to influence and/or correct the aberration correspondingly. This can be done here in an advantageous way in a region in which the aperture is still relatively small.

The bundle of light can be even more effectively separated when the aspheric is arranged in front of the first light bulge.

According to the invention, the sixth optical group can consist only of plane-parallel plates. Of course, it is also possible to provide one or two lenses in the sixth optical group, in which case at least one lens should then have an at least approximately flat surface which is situated adjacent to a further plane-parallel surface, for example an end plate, so that the manipulation chamber according to the invention can then be formed therebetween.

It is also advantageous when lenses in the sixth lens cluster and, if appropriate, also in the fifth lens cluster, that is to say lenses which are situated nearest a wafer in microlithography, have only a positive refractive power. At least two or three appropriate lenses will preferably be arranged at this point.

Advantageous developments of the invention follow from the remaining subclaims and from the exemplary embodiments described below in principle with the aid of the drawing.

It is true that only purely refractive lenses are shown in the exemplary embodiments illustrated, but this invention is not limited to refractive systems, but can also read on catadioptric systems.

Concise Description of the Drawings

In the drawing:

Figure 1 shows a diagrammatic illustration of a projection exposure machine according to the invention having a projection lens,

Figure 2 shows a section through the lower part of the projection lens having an end plate and a lens adjacent thereto with a manipulation chamber therebetween, in an enlarged representation,

Figure 3 shows a manipulation chamber which is formed by a bipartite end plate, in an enlarged representation,

Figure 4 shows an exemplary embodiment having a manipulation chamber and a further gas interspace, in an enlarged representation,

Figure 5 shows a lens section through a first lens arrangement, and

Figure 6 shows a lens section through a second lens arrangement.

Detailed Description of the Invention

The principle of the design of a projection exposure machine 1 is described below with the aid of figure 1. The projection exposure machine 1 has an illuminating device 2 and a projection lens 3. The projection lens 3 comprises a lens arrangement 4 with a multiplicity of lenses 4a (not illustrated in more detail in figure 1) and an aperture stop 5. The lenses 4a are arranged along an optical axis 6. A mask or reticle 7, which is held in the beam path by means of a mask holder 8, is arranged between the illuminating device 2 and the projection

lens 3. The mask 7 is imaged on an image plane 9 by means of the projection lens 3 by a clearly reduced factor. Such masks 7 used in microlithography have a micrometer or nanometer structure which is imaged on the image plane 13 by means of the projection lens 3 in a fashion reduced in size down to a factor of 10, in particular the factor 4. The minimum structures which can still be resolved depend on the wavelength (of the light used for the illumination, and on the aperture of the aperture stop 5, the maximum achievable resolution of the projection exposure machine rising with decrease in the wavelength of the illuminating device 2 and with increasing aperture of the projection lens 3.

A substrate or a wafer 11 positioned by means of a substrate holder 10 is held in the image plane 9.

The dermination of the projection lens 3 in the direction of the wafer 11 forms a flat end plate 12. A last lens 4a of the lens arrangement 4 is located at a spacing from the end plate 12. A manipulation chamber 13, which is sealed off from the surrounding parts, is thereby created between the end plate 12 and the last lens 4a. As may be seen, the side of the last lens 4a facing the end plate 12 is likewise flat, the result being to surrender the manipulation chamber 13 plane-parallel. Of course, it is not mandatory for the side of the last lens 4a facing the end plate 12 to be absolutely plane-parallel. Given appropriately large lens radii, for example with radii R > 3000 mm, preferably > 5000 mm, plane parallelism is likewise achieved, as it were, and it is thereby possible to influence the production of the spherical aberration in the manipulation chamber 13 accordingly.

The manipulation chamber 13 is provided with a pressure connection 14 via which it can be connected to a gas source (not illustrated in more detail) (see also enlarged illustration in figure 2).

By changing the gas composition, which is introduced into the manipulation chamber 13 starting from the gas source 15, and/or a pressure change, changes in refractive index are introduced into the projection lens 3, specifically shortly ahead of the outlet, and so no further imaging errors can be introduced any more. Changing the refractive index creates a spherical aberration which is used to compensate a spherical aberration occurring in the projection lens 3, or else to manipulate it in a desired direction.

Instead of a manipulation chamber between the end plate 12 and the last lens 4a adjacent thereto, it is also possible to achieve a plane-parallel manipulation chamber by dividing the end plate 12 into two. In this case, the two end plate parts 12a and 12b are arranged at a spacing from one another and form the manipulation chamber 13 between their plane-parallel surfaces. Of course, it is necessary in this case for the two end plate parts to be constructed with an appropriate thickness so that no bending occurs (see figure 3). A ratio of thickness d1 to diameter DU1 of 1:5, preferably 1:3 should be observed for this reason.

Figure 4 shows an embodiment having an additional gas interspace 16 as well as the manipulation chamber 13. In order to achieve as high an efficiency as possible for the manipulator, the gas interspace 16 is arranged as near as possible to the wafer 11 such that in this case the manipulation chamber 13 lies correspondingly further to the rear. The gas interspace 16 is likewise created in this case by splitting the end plate 12 into two into the two plate parts 12a and 12b. The interspace 16 is likewise connected to a gas source 15' via a dedicated pressure connection 14'. By contrast with the manipulation chamber 13, however, at least one of the two surfaces situated transverse to the z direction is provided with a slight curvature 17.

If it is known that the projection lens is used at a specific barometric elevation, the following procedure is recommended: Location of use, for example, at an elevation of 1700 meters with correspondingly reduced or increased air pressure by comparison with the lens manufacturer. When the lens is being tuned at the manufacturers, which is located, for example, at sea level or another lower elevation than that of the locations of use, the manipulation chamber is provided with a specifically set gas mixture whose refractive index is higher by the refractive index caused by the pressure difference than that at the location of use. In this way, the manipulation chamber can easily be filled later at the location of use with a conventional filling gas, for example synthetic air, oxygen, nitrogen or helium, at the average pressure at the installation site, and this results in an exactly tuned lens. Natural weather-induced changes in air pressure are now compensated by small pressure changes in the manipulation chamber. The advantage of this method consists in that the customer need only fill the manipulation chamber with conventional filling gas, and only slight pressure differences need be set.

If it is not desired to stipulate where the later location of use should be, the conventional filling gas is used for tuning. However, it is then later necessary to use a gas mixture of higher refractive index at the location of use if the barometric level rises. However, in this case pressure changes owing to the weather are likewise compensated by small changes in the gas pressure in the manipulation chamber.

Sections through the lens arrangements are illustrated by the examples in figures 5 and 6.

The exemplary embodiments relate to a projection lens 3 having a lens arrangement 4 which is subdivided into six optical groups (LG1 to LG6). The first, third and fifth lens groups have a positive refractive power, and the second and fourth lens groups respectively have a negative refractive power. The

subdivision of the lens system into lens groups is set forth below in more detail, the basis having been provided as the directional propagation of the rays.

The first lens group LG1 is positive and terminates with a lens of positive refractive power. The first lens cluster forms a bulge, it being immaterial whether negative lenses are also arranged in the bulge.

The second lens group LG2 has an overall refractive power which is negative. This second lens group LG2 has as first lens a lens constructed on the image side with a concave lens surface. This second lens group LG2 essentially describes a waist. It is not important here, either, whether individual positive lenses are contained in the second lens group LG2, as long as the waist is maintained.

The third lens group LG3 begins with a lens of positive refractive power which has on the image side a convex lens surface, and can be a meniscus. If a thick meniscus lens is provided as first lens, the separation of the lens groups can be conceived inside the lens.

The fourth lens group LG4 has a negative refractive power. This fourth lens group begins with a lens having a negative refractive power which is followed by a plurality of lenses with a negative refractive power. This lens group forms a waist. It is immaterial whether lenses having a positive refractive power are also arranged inside this lens group, as long as this influences the optical path only at a short distance, and so the waist shape of the fourth lens group is maintained.

The fifth lens group LG5 has an overall refractive power which is positive. The first lens of this fifth lens group LG5 has a convex lens surface on the image side. The fifth lens group LG5 forms a bulge.

The lens with the maximum diameter (the bulge), is followed by a further two positive lenses in the fifth lens group LG5, negative lenses also being permissible. The last lens of the fifth lens group LG5 has a concave lens surface on the image side.

The sixth optical group LG6 comprises the optical elements downstream of the fifth lens group up to the image plane.

Such projection lenses are used, in particular, in microlithography. They are known, for example, from DE 199 42 281 A, DE 198 55 108 A, DE 198 55 157 A and DE 198 55 158 A of the applicant and the prior art quoted there. These documents are also intended to be contained in this application.

These lenses in the first and sixth groups conventionally have air clearances which are delimited by a curved surface up to the air clearance between the object plane and first optical surface, and the air clearance between the last optical surface and image plane, at least on one side.

Figures 5 and 6 are of similar basic design. In figure 5, the manipulation chamber 13 is formed between the end plate 12 and the lens 4a in accordance with the principle illustrated in figure 4.

In figure 6, the end plate is of bipartite construction, specifically having the parts 12a and 12b, and the manipulation chamber 13 is located therebetween, as may also be seen from the illustration of the principle in figure 3. A lens is no longer provided in the sixth group in the case of this exemplary embodiment.

A lens 4c having an aspheric can be provided in the first lens group LG1, it being possible for the aspheric to be arranged upstream of the first bulge in the light direction. The

projection lens 3 preferably has a numerical aperture on both sides of at least 0.75, preferably 0.85.

A laser which outputs radiation of wavelength shorter than 250 nm can be used as light source for microlithography.

As the case may be, a pattern contained on the mask 11 is appropriately structured after the development of the light-sensitive layer in the case of the production of microstructure components in which the substrate 11 provided with a light-sensitive layer is exposed to ultraviolet laser light by means of the mask 7 and the projection exposure machine 1.

Figure 5 shows the ability to implement a lithographic lens as regards a manipulable plane-parallel air clearance in the outgoing part of the wafer. It has not so far been known to provide such a thick plane-parallel air clearance and a thick plane-parallel plate in a lens opened widely in such a way.

Aberrations which have so far been corrected in the descending region of the third bulge should now predominantly be corrected in the region of first bulge, first waist, second bulge. It has been found that this even exhibits clearly corrective advantages when the optical system is terminated with a thick plane-parallel plate in the case of the highest aperture. Consequently, this method was taken further where the thickness of the thick plate is clearly increased. In this case, the ratio of thickness to diameter should be at least 1:5. (The two plates act optically like a single thick plate.)

Figure 6 shows a design having a particularly thick plane-parallel plate. It constitutes the solution for three further problems at once.

Very high sine i loadings in the region upstream of the wafer are obtained when correcting highly opened lithographic lenses. The curvatures which the individual lenses can now assume, as a

sphere, now cause aberrations with a much different effect between the edge and middle of the image field (including above the aperture). These are frequently effects which are searched for in the lens and which are particularly provided. Here, in the case of large yields and very high apertures, they can, however, become unmanageable, or certainly at least disturb the correction. The solution now actually constitutes a very thick plane-parallel plate which supplies the desired contribution from spherical overcorrection, but now acts in a completely isoplanatic fashion with reference to the image field. Aperture and image field can now be made very large.

In addition to the corrective advantage, it is also possible to reduce the number of lenses by collecting them to form a thick plane-parallel plate. The number of lens surfaces with a very high angular loading such as is usual upstream of the wafer thereby decreases. The advantages are low costs and less reflection losses, and thus a higher transmission. This is important, in particular, for wavelengths of 157 nm and 193 nm. A further aspect is that the thick plate can substantially simplify the number of mounting parts in a region where there is little space, as is known. Located upstream of the wafer are the most varied image detection sensors which closely adjoin the actual lithographic optical system. The thick plane-parallel plate also creates the possibility here of accommodating more aperture and/or more field within a specific design space. This is also to be seen in that it is then possible, for example, to use the same sensor system for a further generation longer.

A thick plate or thick plates upstream of the wafer are therefore the solution according to the invention for

- a pressure manipulator upstream of the wafer in the lens,
- improved possibility for correction in conjunction with a very high aperture and large field,
- more aperture and field in conjunction with a given design

space, and

- fewer highly loaded surfaces, more transmission.

In the exemplary embodiment according to figure 5, on the first curved surface, an aspheric surface takes over tasks which many lenses just upstream of the wafer have partly also taken over. However, the advantage here is now the extremely low angular loading on the first curved surface. At the same time, because of the good bundle separation it is possible to set a very specific effect with reference to the action between the middle of the image, the zone of the image field and the edge of the image field.

In microlithography, it is also possible in principle to provide a plane-parallel manipulation chamber between a last end plate of a projection lens and a wafer in which the refractive index can be varied by pressure changes and/or changes in gas composition. For this purpose, the interspace between the end plate and the wafer is to be purged with purging gas of appropriate composition and at an appropriate pressure. It is also required in general for this purpose to encapsulate the entire projection lens.

The design arrangement for the lens arrangements illustrated in figures 5 and 6 are to be specified below in each case by way of example. Of course, the features made concrete with the aid of these exemplary embodiments and their combinations can be combined with one another.

Example according to figure 5:
Operating wavelength l = 193.3 nm
Diameter of the image field = 24.6 mm
Image-side numerical aperture NA = 0.85
Image scale (= -0.25
Refractive index n(SIO2) = 1.5603
Refractive index n(CAF2) = 1.5014

Surface	Radius	Aspheric	Thickness	Material	Diameter
OB			32.000	AIR	
1	∞		6.329	SIO2	110.8
2	∞		1.383	HE	112.5
3	-1393.131	A	6.329	SIO2	112.8
4	153.737		14.539	HE	118.0
5	191.890		23.775	SIO2	135.0
6	-359.189		0.678	HE	136.5
7	-827.276		7.196	SIO2	137.7
8	-475.714		0.678	HE	138.8
9	296.346		18.036	SIO2	141.7
10	-561.014		0.678	HE	141.4
11	183.662		19.090	SIO2	137.2
12	-16545.560	A	0.694	HE	135.1
13	326.464		6.329	SIO2	129.2
14	106.348		27.957	HE	118.2
15	-235.452		6.329	SIO2	117.5
16	304.109		15.255	HE	118.0
17	-232.751		6.329	SIO2	118.5
18	174.842		33.179	HE	127.9
19	-135.497		10.857	SIO2	132.8
20	-567.373	A	11.495	HE	160.3
21	-235.399		21.176	SIO2	165.8
22	-145.234		4.213	HE	175.6
23	-1890.770		49.919	CAF2	219.4
24	-156.092		0.678	HE	224.3
25	340.445		66.046	SIO2	255.5
26	-383.246		0.680	HE	254.8
27	137.326		49.212	CAF2	218.0
28	457.970	A	0.678	HE	209.9
29	147.683		15.743	SIO2	181.5
30	120.693		37.797	HE	159.6
31	-420.368		6.329	SIO2	159.6
32	139.505		25.622	HE	140.7
33	-378.597		6.329	SIO2	140.7
34	167.539		39.624	HE	139.8
35	-112.503		8.239	SIO2	139.8
36	504.607		18.193	HE	174.3
37	-369.374		15.678	SIO2	174.6
38	-205.396		1.373	HE	181.7
39	-1692.687		31.888	CAF2	214.3
40	-220.732		1.536	HE	220.3
41	1213.241		32.223	CAF2	256.7
42	-430.691		0.692	HE	259.4
43	735.809		63.006	CAF2	274.9
44	-355.045		9.223	HE	278.5
45	∞		0.633	HE	271.7
AS	∞		0.000	HE	271.7
46	1056.085		20.400	CAF2	272.1
47	-5047.421		0.792	HE	271.5

48	260.901		46.828	CAF2	266.8
49	-1697.534		23.712	HE	264.5
50	-317.482		10.850	SIO2	264.5
51	-488.982		8.402	HE	262.0
52	-339.784		13.562	SIO2	262.0
53	-295.518		0.718	HE	261.9
54	152.565		37.779	CAF2	213.7
55	505.038		3.020	HE	208.6
56	116.772		28.279	SIO2	168.9
57	258.363		16.383	HE	160.8
58	-5272.757	A	10.966	SIO2	154.6
59	323.933		0.897	HE	133.4
60	142.873		27.124	CAF2	121.2
61	∞		8.137	AIR	102.4
62	∞		18.083	CAF2	76.0
63	∞		12.000	AIR	51.1
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In the aspherical formula:

$$z = \frac{\frac{1}{R}h^2}{1+\sqrt{1-(1-EX)\left(\frac{1}{R}\right)^2 h^2}} + \sum_{k=1} c_k h^{2k+2}$$

z is the sagitta; h is the height; R is the radius; EX is the eccentricity; and Ck is the ashperical constant.

ASPHERIC AT SURFACE 3

RADIUS = -1393.13098
EX = .0000000000
C 1 = .4063752600E-07
C 2 = .2071817000E-11
C 3 = -.6785322600E-16
C 4 = .1029460700E-18
C 5 = -.2998039200E-22
C 6 = .3527081700E-26

ASPHERIC AT SURFACE 12

RADIUS = -16545.56046
EX = -43143.0300000000
C 1 = -.4810999900E-07
C 2 = .4047924800E-11
C 3 = -.8963528600E-16
C 4 = .8505763100E-20
C 5 = -.2882210400E-23
C 6 = .5453287000E-27

ASPHERIC AT SURFACE 20

RADIUS = -567.37264
EX = .0000000000

C 1 = -.3925583500E-08
C 2 = -.1562788800E-11
C 3 = -.1025893700E-16
C 4 = -.2599978800E-20
C 5 = .8906747700E-25
C 6 = -.3796689800E-28

ASPHERIC AT SURFACE 28

RADIUS = 457.96974
EX = .0000000000
C 1 = .6773315100E-08
C 2 = -.3998553500E-12
C 3 = -.1364056800E-16
C 4 = -.1474625900E-21
C 5 = -.2509622300E-25
C 6 = .1507291900E-29

ASPHERIC AT SURFACE 58

RADIUS = -5272.75688
EX = .0000000000
C 1 = -.1963426400E-07
C 2 = .2768505300E-12
C 3 = .1262120200E-15
C 4 = -.1811119000E-19
C 5 = .1171493900E-23
C 6 = -.3104888900E-28

Example according to figure 6:
Operating wavelength l = 248.4 nm
Diameter of the image field = 27.2 mm
Image-side numerical aperture NA = 0.8
Image scale β = -0.25
n(SIO2) = 1.5084

Surface	Radius	Aspheric	Thickness	Material	Diameter
OB	∞		32.000	AIR	
1	∞		4.253	AIR	121,9
2	-1143.702		7.789	SIO2	122,9
3	366.821		11.482	AIR	127,5
4	249.157		23.794	SIO2	138,2
5	-289.424		0.750	AIR	139,4
6	329.633		18.667	SIO2	140,7
7	-444.218		0.750	AIR	140,2
8	268.864		16.633	SIO2	135,5
9	1167.441	A	0.750	AIR	131,9
10	360.081		8.628	SIO2	129,2
11	118.445		21.270	AIR	120,1
12	-775.270		7.000	SIO2	119,7
13	156.713		23.965	AIR	118,8
14	-190.304		7.000	SIO2	119,8
15	266.520		27.800	AIR	131,4
16	-141.408		7.149	SIO2	134,4
17	2327.162	A	7.878	AIR	162,8
18	-999.626		32.538	SIO2	169,4
19	-148.399		0.750	AIR	177,5
20	-1179.797	A	40.792	SIO2	207,1
21	-190.467		0.750	AIR	215,0
22	506.448		42.194	SIO2	236,0
23	-318.978		0.750	AIR	236,6
24	156.565		61.867	SIO2	220,3
25	-1909.591	A	0.750	AIR	209,4
26	305.588		22.962	SIO2	186,3
27	178.412		27.808	AIR	157,7
28	-441.206		7.000	SIO2	154,8
29	141.453		34.534	AIR	138,2
30	-176.778		7.000	SIO2	137,5
31	204.086		40.524	AIR	141,8
32	-114.660		7.000	SIO2	143,5
33	1254.417		16.848	AIR	176,1
34	-386.520		31.318	SIO2	181,6
35	-187.128		0.750	AIR	198,8
36	-7551.297		32.372	SIO2	235,1
37	-271.610		0.750	AIR	239,3
38	985.139		48.181	SIO2	264,8
39	-280.307		0.750	AIR	266,7
40	485.845		42.861	SIO2	265,0
41	-19641.172		0.750	AIR	260,0
42	∞		0.750	AIR	259,6
AS	∞		0.000	AIR	259,6
43	413.812		31.899	SIO2	258,5
44	-1463.530		41.090	AIR	257,1
45	-229.000		7.000	SIO2	252,9
46	-761.338		16.518	AIR	258,2

47	-346.924		22.741	SIO2	258,3
48	-221.418		0.750	AIR	260.0
49	265.978		21.446	SIO2	240.4
50	700.398		0.750	AIR	238.8
51	203.760		28.367	SIO2	224.4
52	565.063		0.750	AIR	219.8
53	124.657		33.574	SIO2	185.9
54	255.790		3.089	AIR	175.4
55	192.512		17.352	SIO2	164.2
56	490.117	A	9.135	AIR	155.9
57	∞		57.580	SIO2	148.9
58	∞		2.600	AIR	76.6
59	∞		8.069	SIO2	69.6
60	∞		12.000	AIR	59.5
IM					

In the aspheric formula:

$$z = \frac{\frac{1}{R}h^2}{1+\sqrt{1-(1-EX)\left(\frac{1}{R}\right)^2 h^2}} + \sum_{k=1} c_k h^{2k+2}$$

_z is the sagitta; h is the height; R is the radius; EX is the eccentricity; and Ck is the ashperical constant.

ASPHERIC AT SURFACE 9

RADIUS = 1167.44078
EX = -148.8088700000
C 1 = -.3810274500E-07
C 2 = .1825110100E-11
C 3 = .8703118800E-16
C 4 = -.2547944400E-19
C 5 = .2618280200E-23
C 6 = -.7405173000E-28

ASPHERIC AT SURFACE 17

RADIUS = 2327.16189
EX = -543.6641800000
C 1 = .1496899300E-07
C 2 = -.4053465300E-11
C 3 = -.3692162500E-16
C 4 = .1322169800E-19
C 5 = -.7575130800E-24
C 6 = -.1121083700E-27

ASPHERIC AT SURFACE 20

RADIUS = -1179.79732
EX = 88.7124390000
C 1 = .5780601700E-08

C 2 = .2633543200E-12
C 3 = -.3666325900E-16
C 4 = .793956500E-21
C 5 = -.7002646400E-26
C 6 = -.4010891200E-29

ASPHERIC AT SURFACE 25

RADIUS = -1909.59064
EX = .0000000000
C 1 = .5895489200E-08
C 2 = .4254414900E-13
C 3 = -.4954342300E-18
C 4 = -.9017812800E-21
C 5 = .3307499000E-25
C 6 = -.5028285900E-30

ASPHERIC AT SURFACE 56

RADIUS = 490.11681
EX = -4.7440051000
C 1 = .6613898200E-08
C 2 = -.9371994200E-12
C 3 = .7675398100E-16
C 4 = -.9919946900E-20
C 5 = .9420632400E-24
C 6 = -.4092113200E-28